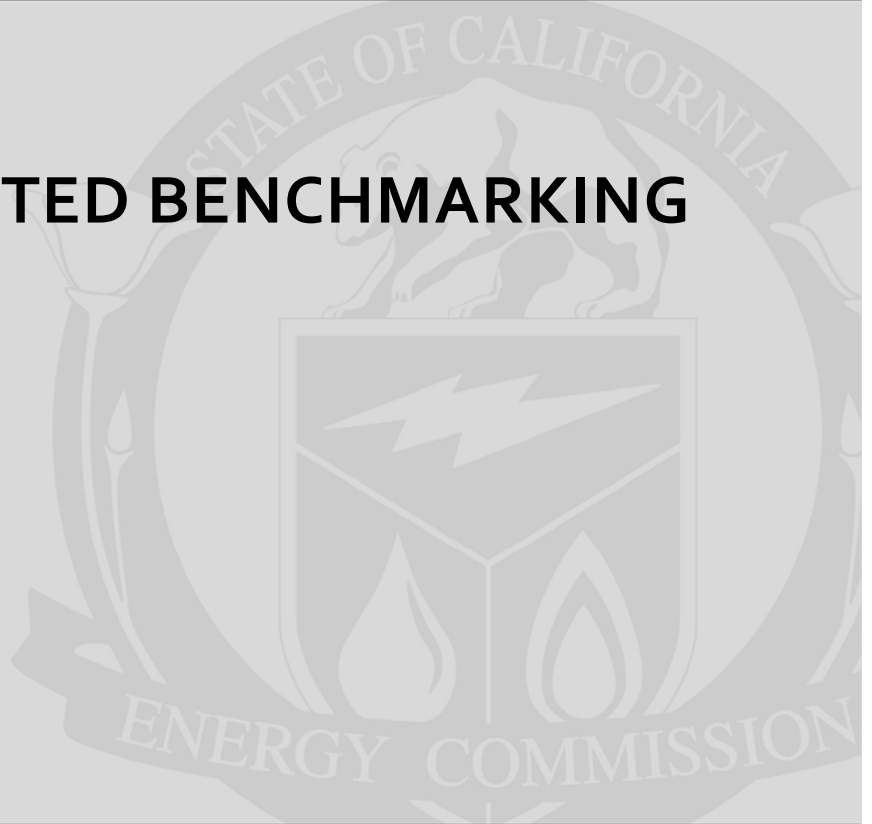


**Energy Research and Development Division
FINAL PROJECT REPORT**

**ENERGYIQ:
ACTION-ORIENTED BENCHMARKING**



Prepared for: California Energy Commission
Prepared by: Lawrence Berkeley National Laboratory



ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The Energy Research and Development Division strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

Energy Research and Development Division funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

EnergyIQ: Action-Oriented Benchmarking is the final report for the Action-Oriented Benchmarking: EnergyIQ Tool Enhancements project (Contract Number 500-09-003) conducted by the Lawrence Berkeley National Laboratory. The information from this project contributes to the Energy Research and Development Division's Buildings End-Use Energy Efficiency Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

This report documents results from the second development phase of the EnergyIQ Action-Oriented Benchmarking tool. Action-oriented benchmarking, like standard building energy benchmarking, is a way of comparing the energy use of comparable buildings and goes beyond standard benchmarking by suggesting practical and cost-effective methods of efficiency improvement. A functional, proof-of-concept tool was developed in the first phase. The improvements implemented in the second phase are described in this report. These improvements included:

- Interoperability with other benchmarking tools used to meet California regulatory requirements. The tool can import building data from the U.S. Environmental Protection Agency's ENERGY STAR® Portfolio Manager benchmarking tool without re-entering data.
- Simulation-based quantitative evaluation of savings potential for specific actions using the Commercial End Use Survey simulation models generates ranges of savings estimates for specific actions, such as installing energy-efficient hardware or changing operating practices in buildings.
- The user interface was significantly improved and expanded to allow for portfolio-level analysis, longitudinal tracking, and identification of potential actions. The underlying methods and robustness of the benchmarking process were also improved. Application programming interfaces were developed for use by third-party software developers.
- A technology transfer plan and activities was developed and carried out to make the knowledge gained and experimental results and lessons learned available to key decision makers.
- The EnergyIQ tool is available for free download from the Lawrence National Berkeley Laboratory website.

Keywords: EnergyIQ, building energy benchmarking, action-oriented benchmarking, energy use intensity, CEUS, CBECS, building commissioning, building energy efficiency, energy upgrades

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS	i
PREFACE	ii
ABSTRACT	iii
TABLE OF CONTENTS.....	iv
LIST OF FIGURES	v
LIST OF TABLES	v
EXECUTIVE SUMMARY	1
Introduction	1
Project Purpose.....	1
Project Results.....	2
Project Benefits	5
CHAPTER 1: Content	7
CHAPTER 2: EnergyIQ: A Web-based Tool for Benchmarking Nonresidential Buildings.....	9
CHAPTER 3: Project History	14
CHAPTER 4: Technology Transfer.....	17
4.1 Overview	17
4.2 Web-based Access to Data, Methods, and Visualizations.....	17
4.3 Web Services	18
4.4 Interoperability with Other Tools.....	20
4.5 Documentation	20
4.6 Demonstration Project	21
4.7 Presentations.....	21
4.8 Sustainability	21
CHAPTER 5: Future Directions.....	22
5.1 Next Steps.....	22
GLOSSARY	24

APPENDIX A: Memo Report on Use Cases Pertaining to the Interoperability of EnergyIQ with Other Benchmarking Tools Used to Meet California Requirements	A-1
APPENDIX B: Memo Report on Role of Energyiq in Asset-Based Benchmarking	B-1
APPENDIX C: Engineering Methodology	C-1

LIST OF FIGURES

Figure 1: Role of Action-Oriented Benchmarking Relative to Whole Building Benchmarking and Investment Grade Energy Audits.....	7
Figure 2: EnergyIQ Home Page	10
Figure 3: Peer Group Selection Page Allows Users to Define Peer Group by Building Type, Size, Vintage, and Location.....	11
Figure 4: Benchmark Results Page Showing Frequency Distribution and Peer Group Information	11
Figure 5: Features Benchmarking Results Showing Distribution of Lighting Ballast Type	12
Figure 6: Track Page Shows Dashboard with Summary Data for Multiple Buildings, as well as User-Selected Benchmark Charts.....	12
Figure 7: ‘MyBuildings’ Energy Use Page Showing Input Data for A User’s Building.....	13
Figure 8: ‘Act’ Page Lists Potential Efficiency Actions and Their Savings for the User’s Buildings	13
Figure 9: Visitation to the EnergyIQ Website, by Country (since inception).	18
Figure 10: Web Services in Context of Back-End Functionality (data, business logic) and Downstream Programmers (“API License”) and End Users.....	19
Figure A1: Portfolio Manager Automated benchmarking Service Console	A-2
Figure A2: Arb’s Cool California Website has a Carbon Footprint Calculator that will Incorporate EnergyIQ Benchmark Data Using the Web Service.....	A-4
Figure A3: Conceptual Scheme for California Benchmarking Portal	A-5
Figure A4: EnergyIQ iPhone app.....	A-6
Figure B1. The Tree Diagram Approach (Based On Cibse Tm 22) Can Summarize the Breakdown of Annual Electricity Use and Compare It with Benchmarks at both the System and Component Levels	B-4

LIST OF TABLES

Table 1: 40 Companies have Expressed Interest in EnergyIQ Web Services.....	20
Table B1: Selected Asset and Operational Metrics in EnergyIQ (* indicates future version of tool)	B-3

EXECUTIVE SUMMARY

Introduction

Energy benchmarking provides an energy use comparison on the energy efficiency of particular buildings to those of other buildings. Buildings' aspects such as size, climate zone location, construction features, equipment, occupancy, and function can be used to normalize performance for a more meaningful analysis. Benchmarking may inspire actions such as weatherstripping and installing insulation, but generally provides no direct guidance on how to improve efficiency.

The goal of EnergyIQ was to move beyond simple energy comparisons to provide practical guidance on the most promising potential efficiency improvements. The project was conducted by Lawrence Berkeley National Laboratory (LBNL) with funding from the California Energy Commission Public Interest Energy Research (PIER) Program.. The first phase of the project began in 2007. The software developed in Phase 1 became the first "action-oriented" benchmarking tool for nonresidential buildings. "Action-oriented" benchmarking has the added capability of providing direct guidance on how to improve efficiency.

The Internet-based tool provided a benchmarking interface to the Commercial End-Use Survey (CEUS) database. This database provides details on energy use and characteristics for about 2,800 buildings and 62 building types and is probably the most thorough survey of its kind ever conducted. The initial software development demonstrated the potential value of action-oriented benchmarking, but further steps were identified to provide a fully functioning and useful tool. These included:

- Capability to assess a building's energy use based on benchmarking results.
- Decision-support information to help define and refine potential corrective actions.
- A more user-friendly interface to allow for different levels of building complexity.
- Wide-scale outreach and training.

Project Purpose

This report addresses Phase 2 of the development, which was undertaken to address the needs identified in Phase 1 and to make the product more responsive to California's legislative initiatives. These include Assembly Bill 1103 (Saldana, Chapter 533, Statutes of 2007), legislation requiring commercial building owners to disclose energy use information when a building is sold, leased or financed, Senate Bill 1 (Murray, Chapter 132, Statutes of 2006), the Millions Solar Roofs Initiative and Executive Order S-020-04, the Green Building Action Plan. Another near-term activity was to establish an electronic link with the U.S. Environmental Protection Agency's (EPA) Portfolio Manager benchmarking tool so that building owners who benchmark their buildings for Assembly Bill 1103 disclosure forms can directly import these data into EnergyIQ to identify efficiency opportunities.

Specific goals for the project included:

- Improving basic functionality, especially the recommended action methods.
- Making the interface more user-friendly and allowing for different complexity levels.
- Actively linking with other tools to meet California benchmarking initiatives and requirements, such as Assembly Bill 1103, Senate Bill 1, and Executive Order S-20-04.
- Making the software robust enough to accommodate a large number of users.
- Conducting outreach and training to encourage the user base to add buildings to the database, which could potentially improve the software's functionality.

The specific objective upon which the project's success was to be evaluated was implementing a production-quality version of EnergyIQ with the following functionality:

- Cross-sectional benchmarking with buildings from the CEUS database, using a variety of different benchmarking measurements to compare buildings.
- Longitudinal benchmarking, which refers to historical benchmarking of a particular building.
- "Dashboard views," which are summaries of several information sets presented on a single screen, summarizing benchmarking analysis.
- A prioritized list of efficiency actions and potential savings inferred from benchmarking results.
- Integrating EnergyIQ with other tools to meet California benchmarking initiatives
- Applying action-oriented benchmarking to several pilot cases.
- A new user interface pilot-tested with users.
- A Web service allowing third-party software developers to access the functionality of EnergyIQ with minimal effort from EnergyIQ developers.
- The ability to help users meet forthcoming California benchmarking requirements.

Project Results

Feedback on the initial deployment was gathered and the site was modified to better serve user needs. Technical features were added, along with extensive improvements in the usability and graphic design of the tool.

A variety of queries were incorporated within EnergyIQ from which users can specify peer groups for comparison. Using the tool, this data can be browsed and compared with a variety of energy metrics for the user's own building. Users can save their project information and return at a later date. The original database is the Commercial End Use Survey. National data from the Commercial Buildings Energy Consumption Survey (CBECS) were subsequently incorporated, allowing benchmarking across the country. CBECS is a survey conducted quadrennially by the U.S. Energy Information Administration to provide basic statistical information about energy consumption and expenditures in U.S. commercial buildings and information about energy-related characteristics of these buildings. Users can import their building data from EPA's Portfolio Manager, avoiding re-entering the data.

EnergyIQ offered a wide array of benchmark metrics, with graphical as well as tabular display. These included energy, costs, greenhouse gas emissions, and a variety of physical characteristics such as building components or operational strategies. The tool supported cross-sectional benchmarking for comparing the user's building to its peers at one point in time, as well as longitudinal benchmarking for tracking the performance of an individual building or enterprise portfolio over time.

Based on user inputs, the tool's "Act" module generated a list of opportunities and recommended actions, providing a range of savings for roughly 100 measures achieved by parametric analysis – evaluating multiple cases with multiple variable combinations – of similar CEUS buildings. Users can then explore various decision-support links for helpful information on how to refine action plans, create design-intent documentation, and implement improvements. Design-intent documentation helped building owners, architects, and engineers make record-keeping easier and ensured that the owner's and designer's upfront vision and goals (for energy efficiency or any other aspect of design) were achieved and were periodically verified through performance measurement. This documentation included information on best practices and links to other energy analysis tools that helped lay the groundwork for investment-grade audits and engineering calculations.

Another important innovation is that EnergyIQ provided a licensable Web service based on the LBNL Action-Oriented Benchmarking System. Through this system, third-party tool developers can tap the data and methods of EnergyIQ for use on their own websites or embedded in energy management systems. An application programming interface was developed to promote this activity, along with tutorials, tool tips, engineering documentation, a demonstration project, presentations, and publications.

The project's origins were rooted in a technology-transfer-focused approach. User-centered development involved extensive market research through surveys and in-depth one-on-one interviews with dozens of potential users. The tool prototypes were vetted with these groups before commitments were made to specific development pathways and user interface choices. This user interface included extensive collaboration with consultants and visual designers specializing in this domain.

User traffic was running at a rate of more than 6,000 visitors per year. As of July 2012, EnergyIQ had been visited 11,500 times by users from 105 countries; 80 percent of the users are from the U.S. and half of those are from California. EnergyIQ has been used to evaluate hundreds of buildings. The tool is available for free download at <http://energyiq.lbl.gov>.

Upgrades should be made to the hosting environment for improved service, reliability, and scalability. These upgrades could be done either in-house at LBNL or by migrating the entire system to a cloud-based environment. These improvements would include:

- Testing the existing system for performance bottlenecks and errors.
- Speeding up the web site, especially for queries.
- Evaluating the available in-house hosting services versus a cloud-based service.

- Migrating the system to the best available service possible, within budget constraints.

Researchers have identified several additional features that would enhance the tool based on direct feedback from users through focus groups, surveys, and one-on-one interactions. These recommendations focus on benchmarking and analytics improvements based on user feedback.

Recommended benchmarking improvements include:

- Allowing users to benchmark against their own portfolio or groups of buildings within their portfolio to attain increasingly meaningful comparisons and to enable portfolio owners to prioritize their interventions more effectively.
- Implementing “compare to other users” benchmarking functionality in addition to existing CEUS and CBECs buildings.
- Importing other datasets such as labs, data centers, and clean rooms to expand and further target the user’s peer building group choices. Emphasis should be put on buildings benchmarked under other PIER-funded projects.
- Filtering by features such as occupancy or building ratings to allow users to further customize their peer group based on building features, such as office buildings with variable air volume systems to attain increasingly meaningful metrics. Allow users to indicate Leadership in Energy and Environmental Design (LEED) and ENERGYSTAR ratings for their buildings, and add this option as a filter for benchmarking.
- More interactive benchmarking “on the fly.” Allow users to add their building data without having to go to the “MyBuildings” page.
- Integrating other building datasets previously funded by the PIER Program and others to provide an additional technology transfer function for these existing Energy Commission work products.

Recommended analytics improvements include:

- Adding peak-power to selectable metrics in the dashboard.
- Providing more ways for normalizing energy use, such as by employee or by hotel occupancy rate, to the extent that these additional metrics are available in the Commercial End Use Survey dataset.
- Providing savings estimates for buildings in other parts of the United States. Based on prior market research and user interviews, this additional feature would increase the appeal of the tool to users who have properties nationally, and who desire a tool that is applicable to their entire portfolio.
- Incorporating benchmarks for code levels and exemplary buildings, perhaps linked to detailed case studies.

The technology transfer strategy includes access to the technology via the Web, application programming interfaces (APIs), and Web services so that third parties can further distribute the system, establishment of an API user community, tutorials/tooltips, engineering documentation, a demonstration project, presentations, and publications. Specifically, this strategy includes:

- Supporting individuals using the tool.
- Promoting and supporting third-party uses of the Web service API offered for integrating EnergyIQ functionality into third-party websites, handheld applications, and building energy management systems.
- Enhancing API platform documentation and proactively reaching out to third-party software developers via <https://developers.buildingsapi.lbl.gov/eiq/eiq-home>.
- Developing a long-range strategy for hosting the software.

The overriding objective going forward is for the EnergyIQ action-oriented energy benchmarking tool to support Energy Commission and broader California policy objectives for improving the energy-efficiency of the commercial building stock in general, and widespread benchmarking of buildings in particular.

Distinct from other sorts of research efforts, maximizing the value of software to its user community requires a degree of continued update and user support and high-value incremental improvements to the existing EnergyIQ tool and underlying Web service, informed by feedback received from users.

Project Benefits

The EnergyIQ action-oriented energy benchmarking tool benefited ratepayers by improving the energy efficiency of California's commercial building stock. EnergyIQ achieved this by providing the owners and operators of buildings with unprecedented and easy-to-use decision support functions to aid in their energy efficiency investments. Energy efficiency is in the top tier of the Energy Commission's "loading order" of objectives. Ratepayers operating buildings with higher energy efficiency will benefit by paying lower utility bills. Buildings consuming less energy reduce the strain on California's power grid resources, reducing the required spending by utilities and benefitting ratepayers, and also gain improved environmental and economic characteristics.

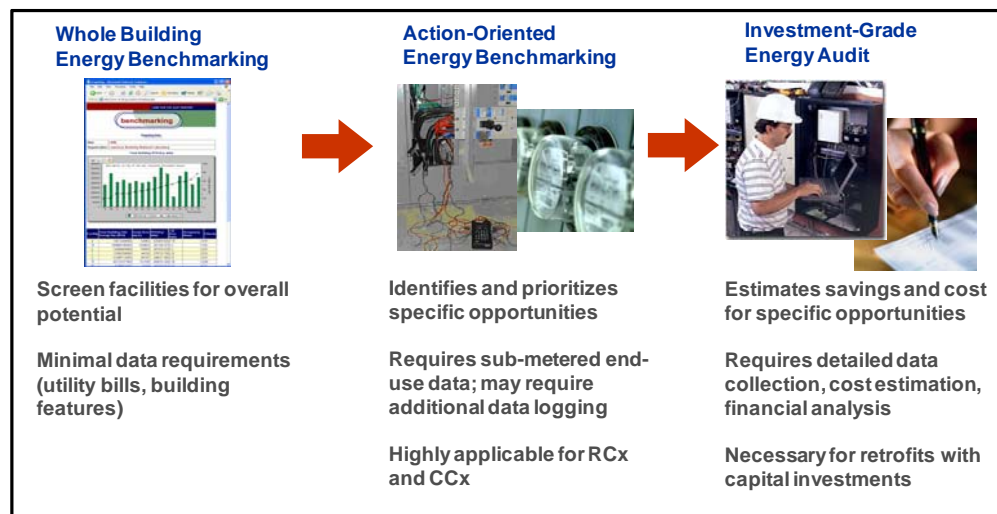
CHAPTER 1:

Content

In isolation, benchmarking can inspire action but provides no practical guidance. With sponsorship from the California Energy Commission's Public Interest Energy Research (PIER) program the U.S. Department of Energy's Lawrence Berkeley National Laboratory (LBNL) is building the next generation of energy benchmarking methods to address this problem. EnergyIQ—the first "action-oriented" benchmarking tool for nonresidential buildings—bridges this gap by providing a standardized opportunity assessment based on benchmarking results, along with decision-support information to help refine action plans. The tool is available at <http://energyiq.lbl.gov>

Action-oriented benchmarking improves on simplified benchmarking processes and helps lay the groundwork for investment-grade audits and engineering calculations, as suggested in Figure 1.

Figure 1: Role of Action-Oriented Benchmarking Relative to Whole Building Benchmarking and Investment Grade Energy Audits



Source: Lawrence Berkeley National Laboratory

The Energy Commission's PIER Program originally conceived the EnergyIQ project, and sponsored subsequent development of the tool. AB1103 was a strong driver for the original PIER Program project, and the Energy Commission's perspective has been, that while EnergyStar is the statutory "compliance" pathway, building owners should be encouraged to extend their analysis beyond the minimum requirements by using EnergyIQ. In conjunction with this, the Energy Commission's planned "AB1103 Portal," will provide links to both EnergyIQ and the statutory tool. Under prior work, EnergyIQ has been tailored to allow automated importing of user data from Portfolio Manager for just this reason. Similarly, utility-

bill disclosure requirements under AB531 remove a barrier to benchmarking using systems like EnergyIQ.

EnergyIQ benchmarks energy use, costs, and features for an array of building types and provides a carbon-emissions calculation for the energy consumed in the building, an important part of any businesses' overall "carbon footprint". The additional action-oriented benchmarking recommendations fundamentally improve on previously available simplified benchmarking processes, and help lay the groundwork for investment-grade audits and professional engineering calculations. The concepts and prototype implementation of EnergyIQ, was documented in Phase 1, via two peer-reviewed publications (Mills et al., 2008; Mathew et al., 2008).

EnergyIQ represents a major advancement beyond LBNL's widely used Cal-Arch (which it replaces), providing a deeper level of analysis compared to more generalized whole-buildings tools such as the ENERGY STAR® Portfolio Manager.

In developing EnergyIQ, we surveyed potential users representing half a billion square feet of building floor area. We also incorporated best-practices recommended for energy benchmarking and tool design published by the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE).

CHAPTER 2:

EnergyIQ: A Web-based Tool for Benchmarking Nonresidential Buildings

A variety of databases are incorporated within EnergyIQ from which users can specify peer groups for comparison. Using the tool, this data can be browsed visually and used as a backdrop against which to view a variety of energy benchmarking metrics for the user's own building. Users can save their project information and return at a later date to continue their exploration. The original database is the California Commercial End-Use Survey (CEUS), which provides details on energy use and characteristics for about 2,800 buildings and 62 building types. CEUS is likely the most thorough survey of its kind ever conducted. National data from the Commercial Buildings Energy Consumption Survey (CBECS) were subsequently incorporated, allowing benchmarking across the country. As an additional service to users, users can import their building data from the Environmental Protection Agency's Portfolio Manager.

Through EnergyIQ's interface, users can browse charts and tables dynamically generated from internal databases until they find a peer group and one or more metrics and views that they wish to compare to their own building. A key tool feature is that it minimizes the time and data required from the user by tailoring input data requirements to the desired output.

EnergyIQ offers a wide array of benchmark metrics, with graphical as well as tabular display. These metrics include energy, costs, greenhouse-gas emissions, and a large array of characteristics (e.g. building components or operational strategies). The tool supports cross-sectional benchmarking for comparing the user's building to its peers at one point in time, as well as longitudinal benchmarking for tracking the performance of an individual building or enterprise portfolio over time.

Based on user inputs, the tool's "Act" module generates a list of opportunities and recommended actions, providing a range of savings for approximately 100 measures achieved by large-scale parametric analysis of similarly filtered CEUS buildings. Users can then explore various decision-support links for helpful information on how to refine action plans, create design-intent documentation, and implement improvements. This includes information on best practices, links to other energy analysis tools, and more.

EnergyIQ provides a licensable web service based on the LBNL Action-Oriented Benchmarking System. Through this system, third-party tool developers can utilize the data and methods of EnergyIQ for implementation on their own web sites or embedded in energy management systems.

The researchers conducted very extensive usability analyses while developing the graphical user interface (GUI). Consistent with a current commercial software paradigm that decreasingly relies on tutorials to educate users, it has been possible to develop a largely self-evident EnergyIQ GUI. Carefully crafted context-sensitive tooltips provide the necessary user education

offering for EnergyIQ users. For users of the Application Programming Interfaces (APIs), more in-depth tutorial resources are needed in order to explain the complexity of the system (<https://developers.buildingsapi.lbl.gov/eiq/eiq-home>).

Figures 2-8 show selected screen images of from EnergyIQ.

Figure 2: EnergyIQ Home Page

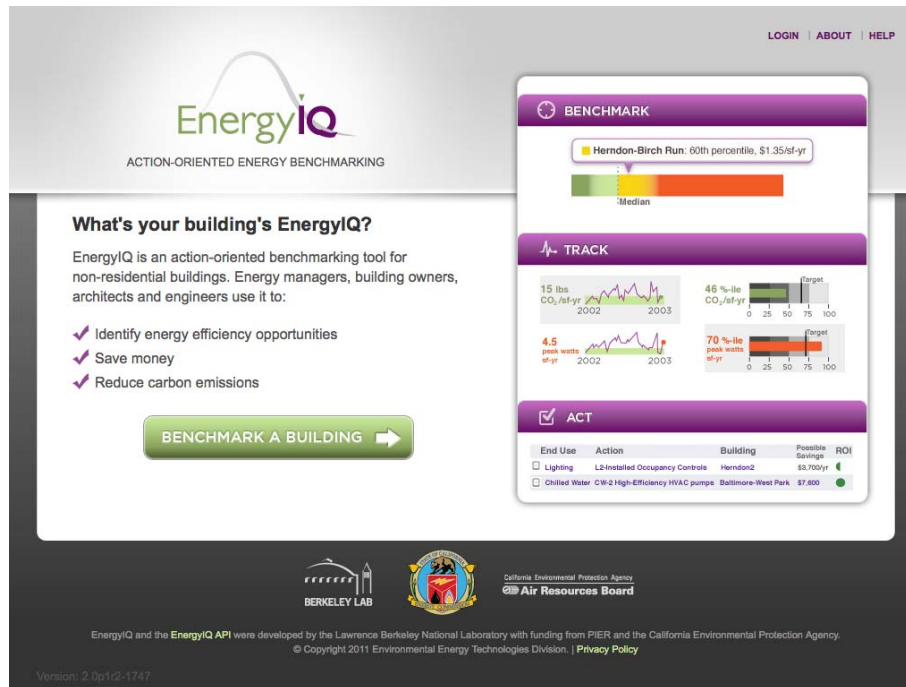


Figure 3: Peer Group Selection Page Allows Users to Define Peer Group by Building Type, Size, Vintage, and Location

Figure 4: Benchmark Results Page Showing Frequency Distribution and Peer Group Information

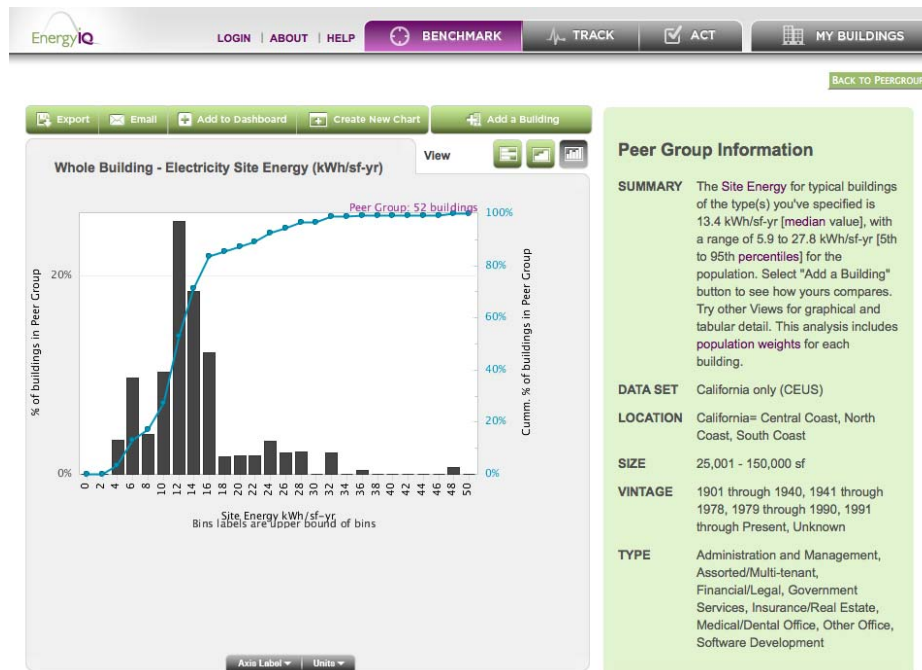


Figure 5: Features Benchmarking Results Showing Distribution of Lighting Ballast Type

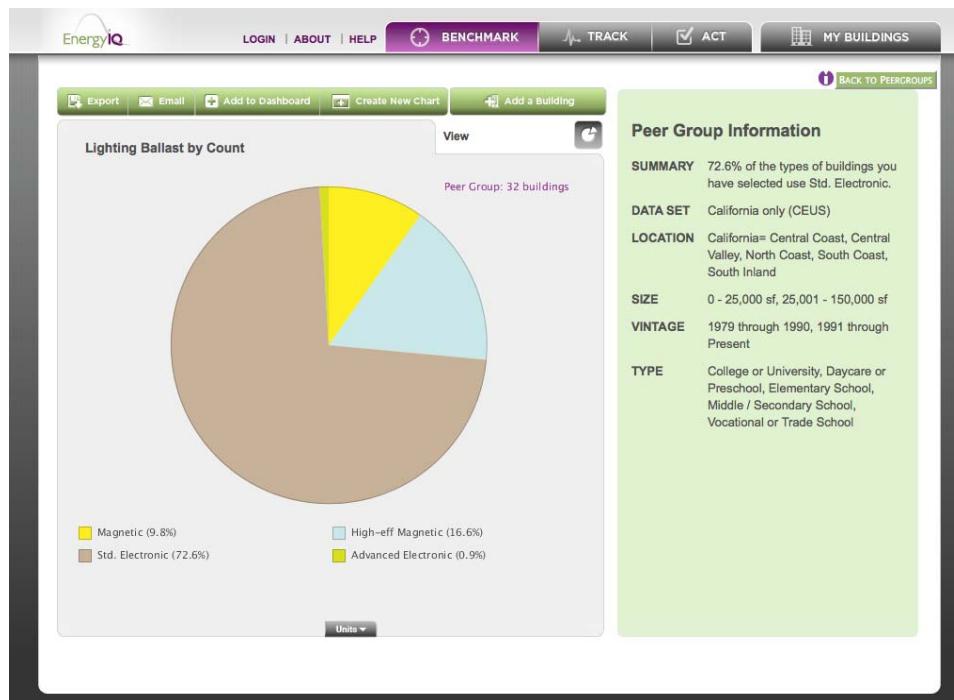


Figure 6: Track Page Shows Dashboard with Summary Data for Multiple Buildings, as well as User-Selected Benchmark Charts.

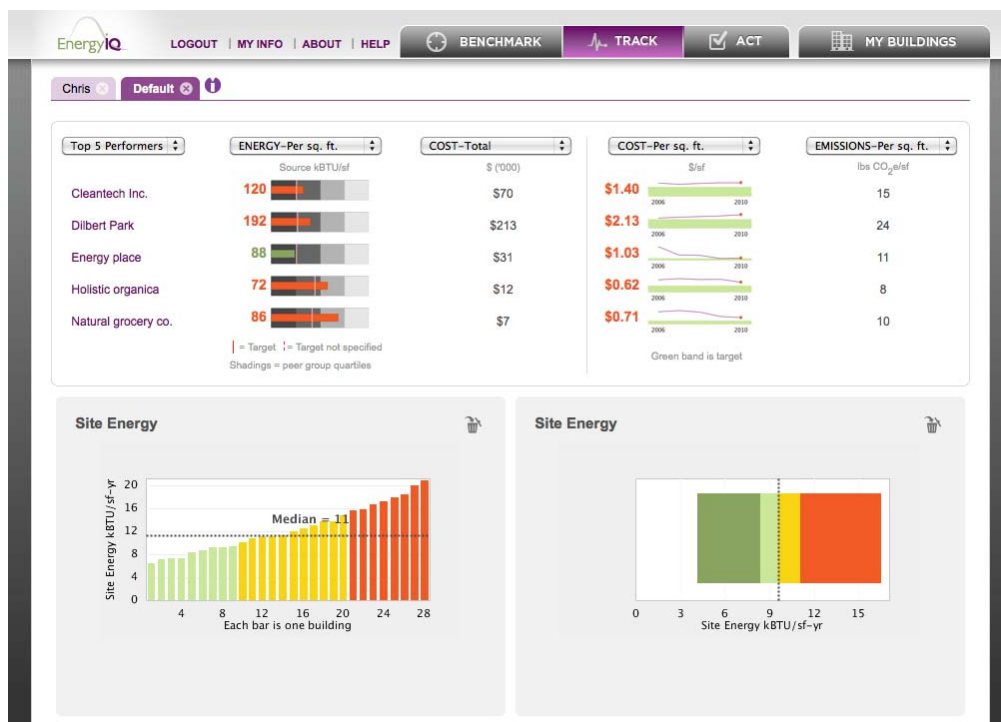


Figure 7: 'MyBuildings' Energy Use Page Showing Input Data for A User's Building

[LOGOUT](#) | [MY INFO](#) | [ABOUT](#) | [HELP](#)

BENCHMARK

TRACK

ACT

MY BUILDINGS

My Buildings ▶ Cleantech Inc.

[Building Details](#) | [Peer Group](#) | [Energy Use](#) | [Features](#)

	Electricity (grid)	Natural Gas	ADD ENERGY TYPE
Annual Use	525,000 kWh	680 MBTU	
Annual Cost	\$63,000	\$7,140	
End date	12/31/2010	12/31/2010	
Start date	01/01/2010	01/01/2010	
Lighting	180,000 (26470.59%)		
Heating		600 (88.24%)	
Cooling	100,000 (14705.88%)		
Ventilation	95,000 (13970.59%)		
Service Hot Water		80 (11.76%)	
Office Equipment	150,000 (22058.82%)	0 (0.00%)	
Refrigeration			
Cooking			
Motors			
Air Compressors			
Process			
Miscellaneous			
Unassigned	0 (0.00%)	0 (0.00%)	
Source Energy Factor	2.940000 Source/Site	1.047000 Source/Site	
CO ₂ Rate	365.000000 lbs. CO ₂ /MBTU	116.732000 lbs. CO ₂ /MBTU	
CO ₂ e Rate	367.000000 lbs. CO ₂ /MBTU	117.040000 lbs. CO ₂ /MBTU	

Figure 8: 'Act' Page Lists Potential Efficiency Actions and Their Savings for the User's Buildings

EnergyIQ

LOGOUT | MY INFO | ABOUT | HELP

BENCHMARK

TRACK

ACT

MY BUILDINGS

Actions

PrintSendExport

ArchiveDelete

<input type="checkbox"/>	End Use	Action	Building	Potential Savings	ROI	Status	Notes
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		20 July 2009	
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		20 July 2009	
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		20 July 2009	
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		20 July 2009	View
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		20 July 2009	
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		Not applicable	View
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		Pending	
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		Rejected	
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		20 July 2009	
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		20 July 2009	
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		20 July 2009	View
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		20 July 2009	View
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		20 July 2009	
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		20 July 2009	View
<input type="checkbox"/>	Lighting	L-2 Installed occupancy controls	Herndon-Birch Run	\$\$-\$\$		20 July 2009	

Active | Archived | Deleted

Previous

 | 30-45 of 138 |

Next

CHAPTER 3:

Project History

EnergyIQ development has proceeded under two phases of work. In Phase 1, a conceptual design was developed and assessed to meet the large target audience needs through extensive focus groups and other methods. An initial web implementation was deployed with simplified functionality.

In Phase 2, feedback on the initial deployment was gathered and the site modified to better serve user needs. The tool was not actively promoted, pending further refinements. Major additional technical features were added in tandem with substantial investment in improving the usability and graphic design of the tool.

The following is a more detailed outline of work accomplished through Phase 2.

Under Contract 500-99-013 work order 201-P (Phase 1) LBNL created a publicly accessible web-based prototype of EnergyIQ. This work order involved the following accomplishments:

Market Research:

- Review of past benchmarking literature and experience
- Survey of potential users of the tool included 100 respondents (20 percent response rate) representing 500 million square feet of space
- End-user review of initial mockups (23 respondents [20 percent response rate])

Development of Methodology for Dynamic Benchmarking Based on CEUS Database Queries:

- Created dynamic web interface to a version of the CEUS database provided to LBNL by Energy Commission
- Customized whole-building and end-use energy benchmarking (~14 metrics)
- Features benchmarking (~85 features)
- Filters for building type, climate, vintage, size and peer group
- Multiple chart types
- Multiple indicator types
- Database with CEUS data, and storage of user-entered data
- Extensive associated help screens and documentation
- Exportable graphics and tables (to Word and Excel)

Infrastructure:

- Oracle database
- Bug-tracking system
- Automated backups
- Documentation
- Conceptual design of a web service infrastructure, which allows others to build

their own portal to the AOB system.

Mockups of Ancillary Screens (conceptual design, not implemented):

- Overall dashboard with consolidated results across metrics and multiple buildings
- User screens for managing portfolios of buildings
- Longitudinal views to track trends over time
- Potential actions (~50) with coarse qualitative rating in terms of applicability and impact (based on user inputs) as well as cost-effectiveness (in general terms, not based on user input).
- Improve EnergyIQ usability by continuing the development of the top-level dashboard for snapshot analysis and comparison across multiple projects, metrics, etc. Enhance design and implementation of user-input forms.

Other Activities:

- Increased library of actions and improve inference/mapping methods, based on user-inputs (aside from potential simulation-based action methodology, noted below).
- Conducting pilot testing of EnergyIQ on a selection of state buildings that were benchmarked as part of AB 1103. This task included initial meeting(s), in-person guidance on using the tool, interpreting results, assessing the level of user effort required and practical constraints on data availability/collection, and feedback on the user interface.

Phase 1 yielded a functioning, publicly accessible web-based EnergyIQ prototype. All goals were met and some considerably surpassed. While the prototype tangibly demonstrates the action-oriented benchmarking potential, several gaps remained:

- Some of the core functionality still required development, especially the action inference methods.
- Feedback from users suggested that the interface needed to be more user-friendly, and allow for different levels of complexity.
- The software was not yet “production-quality” i.e., not robust enough to accommodate a large number of users, or even intensive use by a single user.
- There was not yet active outreach and training for the software. Action-oriented benchmarking involves significantly more data collection, input, and results than simple whole-building benchmarking. Lack of outreach and training will hinder wide-scale use of the tool.

Under Contract 500-09-003, Phase 2, the researchers developed a production-quality version of EnergyIQ that improved the tool and responded to California benchmarking initiatives, and provided outreach and training to engage tool users. Specific achievements:

- Implementation of a production quality version of EnergyIQ, with the following core functionality
 - Cross-sectional benchmarking with CEUS database
 - Longitudinal benchmarking
 - “Dashboard” views summarizing benchmarking analysis
 - Prioritized list of efficiency actions inferred by benchmarking results
- Development of a new user interface, pilot-tested with users
- Development of a web service that allows third party software developers to use the functionality of EnergyIQ with minimal effort from EnergyIQ developers.
- Development of an action-inference module (the “Act” page) that identifies efficiency actions and their potential savings for users’ facilities
- Establishment of data-import from EnergyStar’s Portfolio Manager. Reducing the need for dual-entry removes a major barrier to the use of the tool.
- Created engineering documentation, integrated with EnergyIQ website

One avenue explored during the planning stages was the extension of EnergyIQ, to what is commonly referred to as “asset-based” benchmarking (Appendix B). Several benchmarking schemes are today making a distinction between Asset Rating (AR) and an Operational Rating (OR). AR is a measure of the energy efficiency of the building’s physical components, assuming standard occupancy and operational conditions.

OR is the measure of the building’s energy efficiency based on actual energy use. AR is especially useful for stakeholders in the sale or lease of buildings, while OR is primarily useful for building operators to track and reduce the energy use of their buildings.

Building-level AR and OR indicate relative scale of the opportunities to improve assets or operations. For example, a building whose operational rating is much lower than its asset rating should probably focus on retro-commissioning before considering asset retrofits. The building-level AR and OR are limited in their ability to provide more specific information on efficiency opportunities – they tell you where you are, but not why. This scenario is where EnergyIQ can add value.

EnergyIQ also has the potential to provide a building-level AR that is coarser, but not as data intensive as that from other methodologies, such as BuildingEQ, using the CEUS simulation models. Some of the technical capability to generate a coarser AR, has been implemented. An AR feature could be incorporated in a future version of EnergyIQ.

CHAPTER 4:

Technology Transfer

4.1 Overview

The project's origins are rooted in a technology-transfer-focused approach. User-centered development involved extensive market research through surveys and in-depth one-on-one interviews with dozens of potential users. The tool prototypes were vetted with these groups before commitments were made to specific development pathways and user interface choices. This vetting process included extensive collaboration with consultants and visual designers specializing in this domain.

Application Programming Interfaces (APIs) are important to facilitate the use of software tools by third parties because the APIs precisely define the data format and content exchanged by the software, but relieve the third-party developer of the need to understand exactly how the underlying program operates. This feature allows them to concentrate on how they are going to use the data provided by EnergyIQ, and on their own user interface.

The technology transfer strategy includes access to the technology via the web, APIs and web services so that third parties can further distribute the system, establishment of an API user community, tutorials/tooltips, engineering documentation, a demonstration project, presentations, and publications.

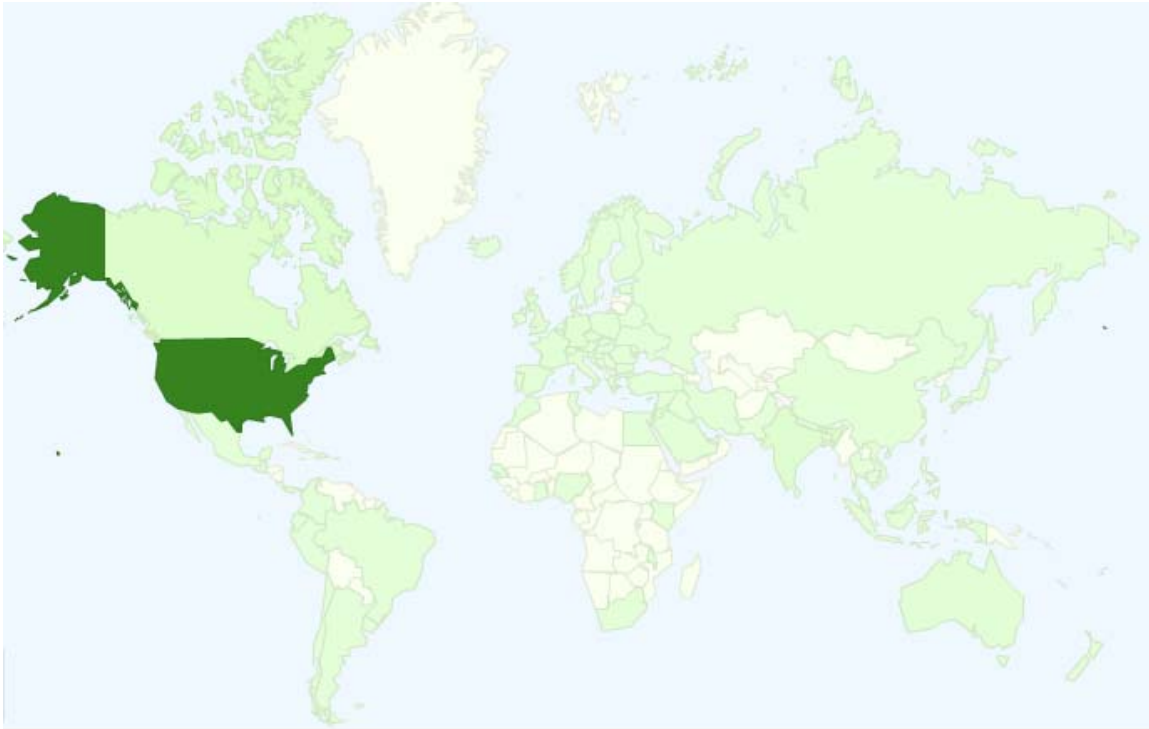
4.2 Web-based Access to Data, Methods, and Visualizations

The underlying technology takes the form of algorithms for computing meaningful building energy metrics, an Internet platform for providing target-audience access to the technology, and a web-based graphical user interface (GUI) for presenting the information.

Technology transfer occurs when, EnergyIQ is accessed by individuals who make energy decisions in nonresidential buildings.

User uptake has been significant, despite a low promotion level while the tool was under development. User traffic is currently running at a rate of over **6,000 visitors per year**. As of July 2012, EnergyIQ had been visited 11,500 times by users from 105 countries (Figure 9), but 80 percent the users are from the U.S. and half of those are from California. The site is available at no charge to users.

Figure 9: Visitation to the EnergyIQ Website, by Country (since inception).



Source: Lawrence Berkeley National Laboratory

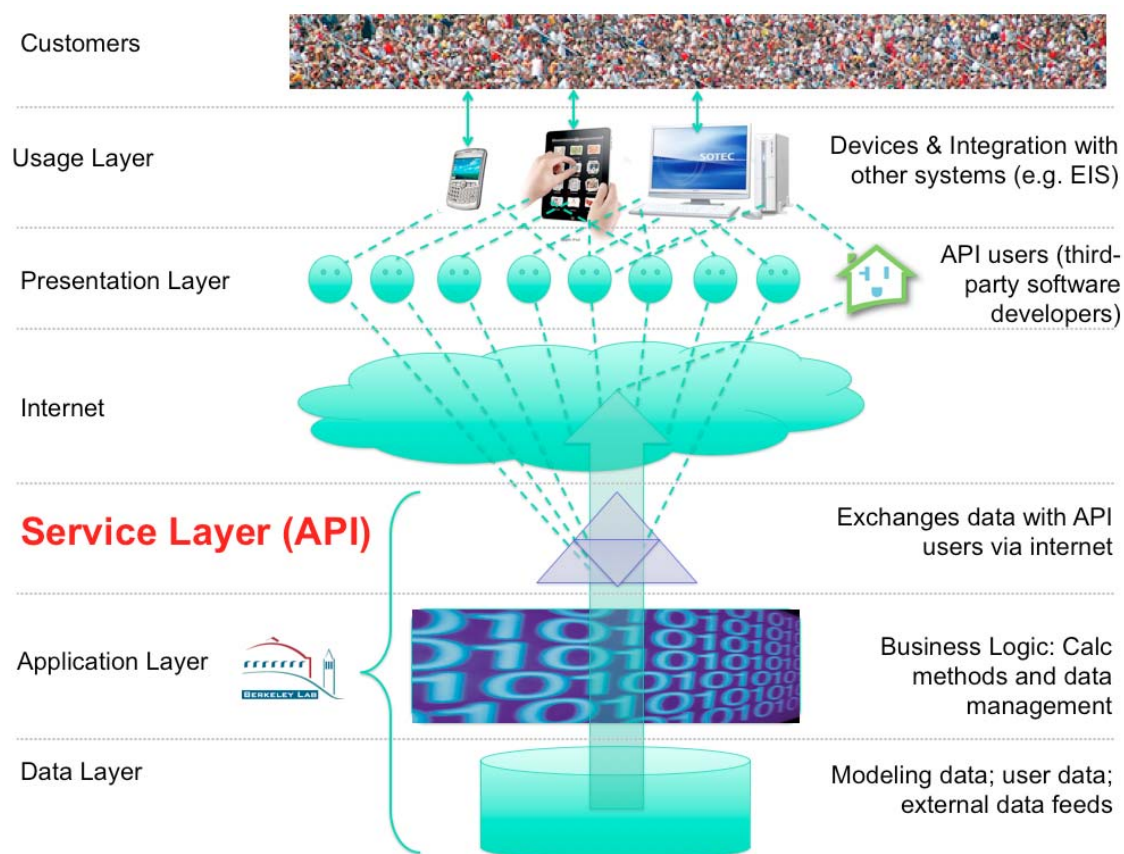
4.3 Web Services

In parallel with the public-facing GUI, the project has developed web services that enable third-party software developers to integrate our technology into their own software and energy management systems (Mills and Mathew 2012). These web services take the form of Application Programming Interfaces, or APIs.

The researchers created an extensive web platform to enable these third-party developers to access these web services. The core approach involves providing the APIs, shown in Figure 10, to third-party software developers. This approach enables the “Action-Oriented Benchmarking” methods underlying EnergyIQ, to be utilized in other software tools (see <https://developers.buildingsapi.lbl.gov/eiq/eiq-home> for further details).

Given the replication potential of this offering, technology transfer via APIs promises to reach even more people than LBNL’s own GUI. Thirty-seven companies and other entities have taken the initial step towards registration or have otherwise inquired about use of the APIs (Table 1). This group includes significant players such as Johnson Controls. The California Air Resources Board has already initiated the use of EnergyIQ within its CoolCalifornia carbon footprint tool. The California utilities have also expressed interest in utilizing the web services.

Figure 10: Web Services in Context of Back-End Functionality (data, business logic) and Downstream Programmers (“API License”) and End Users



Source: Lawrence Berkeley National Laboratory

Energy Information Systems (EIS) vendors have expressed strong interest in incorporating EnergyIQ’s action-oriented benchmarking analytics into their dashboards. EIS systems are typically integrated with utility meters and are used to track energy use and costs. Most EIS vendors offer basic analytics such as baselining, but do not include cross-sectional benchmarking or identification of efficiency opportunities. An API link with EnergyIQ can significantly enhance their existing functionality with relatively low level of effort. For users that are already invested in a particular EIS, this feature is especially attractive because they will be able to access its functionality without having to acquire or learn new software.

The researchers have assembled a 400-name email list of individuals specifically interested in energy benchmarking, and utilize the list to communicate updates to stakeholders.

The central tenet of the Technology Transfer strategy is to make the system available for use by third-party software developers. A third round of Energy Commission funding has been obtained to complete development, making the service as attractive to its target audiences as possible, and to obtain sufficient time to cultivate API users.

Table 1: 40 Companies have Expressed Interest in EnergyIQ Web Services

Registered on API Platform	Inquiry about APIs
ACCO Engineered Systems Adage Technologies California Air Resources Board Energy Commission C3 The Efficiency Network Enovity ESCOM Honeywell Internachi Lucid Design Group Main Sleuth Milton Partners MNCEE New Buildings Institute NORESCO PeoplePower Co Perpetual Energy Services Techno-lean UC Berkeley WES	AESC CBRE Corey Kreidler CSL Energy Decent Energy, Inc. Gary Dean GovtProperty.com Hara ISCPGH Johnson Controls McGraw Hill NOI Engineering Opencommons.org PeoplePower PG&E Project DX PSD Consulting SAP Scientificconservation.com Southern California Gas State of Mass Stopwaste.org Sustainable-IQ Symbiotic Engineering TEAA Tendril Wattzy WRNS Studio

The key user community will ultimately be the API users. In conjunction with the API platform, the research team created an on-line forum for these users.

4.4 Interoperability with Other Tools

Enabling the EnergyIQ system to interact and interoperate with other tools is a key strategy for user adoption and technology transfer (See memo report in Appendix A). The APIs enable these processes, as does the download feature from Energy Star's Portfolio Manager. The AB1103 portal, once developed by the Energy Commission, will also serve this purpose.

4.5 Documentation

An additional leg of the technology transfer strategy is to make the energy engineering methods transparent, such that others can replicate them. This documentation is organized in a publicly accessible website (see <https://sites.google.com/a/lbl.gov/energyiq/>).

4.6 Demonstration Project

The research team is also supporting the technology transfer through a demonstration project with the U.S. General Services Administration (GSA). The project goal, funded by the GSA, is to develop and pilot test a tiered benchmarking approach using EnergyIQ on a “mini-portfolio” of GSA buildings in California, with the aim of developing a benchmarking strategy that could be deployed on a larger scale across the GSA.

4.7 Presentations

More traditional technology transfer activities were also pursued within the project, as follows:

- Multiple webinars to key stakeholders (including Technical Advisory Group [TAG] meetings, which were well-attended by prospective EnergyIQ users).
- Briefing to the California Utilities Benchmarking Working Group – September 21, 2011
- Presentation to the Emerging Technologies Coordinating Council (ETCC) – November 9, 2010
- Briefing to U.S. Green Building Council staff – May 4, 2011
- Discussion with the California Advisors on Measured Performance – April 27, 2010
- Pacific Gas and Electric (PG&E) Symposium on Information Visualization in Commercial Buildings at the Pacific Energy Center, San Francisco – April 13, 2010
- ACG 6th Annual Conference on Total Building Commissioning – April 6, 2010
- TRIRIGA “Learn from the Leaders” Webinar Series – May 20, 2009

4.8 Sustainability

Intrinsic in any public-goods software development project is the dilemma of one-time funding for development juxtaposed against ongoing service maintenance and long-term user support. The researchers endeavored to minimize such costs and have arranged for the LBNL Information Technologies Department to provide no-cost hosting of the website.

As the APIs come into use, the research team hopes that third-party websites will spring up, receiving their own private- or public-sector funding outside of the LBNL/PIER Program system. If at any time, maintaining the EnergyIQ GUI becomes cost-prohibitive, these third-party sites will be able to persist as long as the back-end APIs remain available, even if the EnergyIQ.lbl.gov user interface is no longer maintained. If there is no funding, even to maintain without enhancing the existing system, the research team will pursue transferring the entire system to a third party and thereby moving it completely out of LBNL. This scenario would be attractive to such vendors, as they are potentially being handed a completed software package along with paying customers. Under this scenario, the option would always remain for Energy Commission, and/or other entities, to continue funding LBNL to play the hosting role, but this would not be essential.

CHAPTER 5: Future Directions

The overriding objective going forward is for the EnergyIQ “action-oriented” energy benchmarking tool to support Energy Commission/PIER Program and broader California policy objectives for improving the energy-efficiency of the commercial building stock in general, and widespread building benchmarking in particular.

Unlike other sorts of research efforts, software products require continued update and user feedback support to enable the high-value incremental improvements to the existing EnergyIQ tool and underlying web service.

Under Phase 2 development, extensive user interviews were conducted and EnergyIQ underwent a major expansion in functionality along with a full redesign of the user interface.

The technology transfer strategy has been well validated by the number, diversity and interest level of users.

5.1 Next Steps

Next steps should include:

1. Infrastructure Enhancements

Upgrades should be made to the hosting environment for improved service, reliability, and scalability. These upgrades could be done either in-house at LBNL or by migrating the entire system to a cloud-based environment. This enhancement would entail the following activities:

- Test existing system for performance bottlenecks, errors.
- Refactoring to speed up site, especially queries.
- Evaluate the available in-house hosting services versus a cloud-based service. Migrate system to the best-available service possible, within budget constraints.

2. Incremental Feature Additions

Based on direct feedback from users through focus groups, surveys, and one-on-one interactions, the team identified several additional features that would enhance the tool. Following are candidate avenues for improvement in benchmarking and analytics:

- Improved benchmarking
 - Allow users to benchmark against their own portfolio or groups of buildings within their portfolio to attain increasingly meaningful comparisons and enable portfolio owners to prioritize their interventions more effectively.
 - Implement “Compare to other users” benchmarking functionality (in addition to existing CEUS and CBECS buildings).

- Import other datasets (e.g., labs, datacenters, cleanrooms) to expand and further target the user's choices of peer group of buildings. Emphasis would be put on buildings benchmarked under other PIER Program-funded projects.
- Filtering by features (e.g., occupancy, building ratings, etc.) will allow users to further customize their peer group based on building features (e.g., office buildings with VAV systems) and attain increasingly meaningful metrics. Allow users to indicate LEED and EnergyStar ratings for their buildings, and add this as a filter for benchmarking.
- More interactive benchmarking "on the fly." Allow users to add their building data "in-line" on the benchmarking chart (without having to go to the MyBuildings page).
- Integrate other building datasets previously funded by the PIER Program and others, the project provides a specific technology transfer function in increasing utilization of those existing Energy Commission work products.
- Improved analytics
 - Add peak-power to selectable metrics in the dashboard ("Track" tab).
 - Provide more ways to normalize energy use (e.g., by employee or by hotel bed-night)—to the extent that these additional metrics are available in the CEUS dataset—and attain increasingly meaningful metrics.
 - Provide savings estimates for buildings in other parts of the US. Based on prior market research (user interviews), this would increase the appeal of the tool to California-based users who frequently have properties nationally, not just in California and would not adopt a tool like EnergyIQ unless it was applicable to their entire portfolio.
 - Incorporate benchmarks for code levels and exemplary buildings, perhaps linked to more elaborated case studies.

3. Technology Transfer

- Support individuals utilizing the tool.
- Promote and support third-party uses of the web services APIs we offer for integrating the EnergyIQ "action-oriented benchmarking" functionality into third-party websites, handheld applications, building energy management systems, etc.
- Enhance documentation of API platform and proactive outreach to third-party software developers via <https://developers.buildingsapi.lbl.gov/eiq/eiq-home>.
- Develop long-range strategy for hosting beyond this funding period.

GLOSSARY

ABS	Automated Benchmarking System
API	Application programming interface
AR	Asset Rating
ASHP	Air source heat pump
ASHRAE	American Society of Heating, Refrigerating, and Air-conditioning Engineers
CBECS	Commercial Buildings Energy Consumption Survey
CEUS	California Commercial End-Use Survey
DEC	Display Energy Certificate
EEMA	Energy efficiency measure analysis
EIA	U.S. Energy Information Administration
EIS	Energy information system
EPA	U.S. Environmental Protection Agency
EPC	Energy Performance Certificate
ETCC	Emerging Technologies Coordinating Council
GF	Gas furnace
GSA	U.S. General Services Administration
GUI	Graphical user interface
HVAC	Heating, ventilation, and air conditioning
kW/ton	Chiller efficiency, kilowatts per ton of cooling capacity
LBNL	Lawrence Berkeley National Laboratory
LEED	Leadership in Energy and Environmental Design
LPD	Lighting power density
OR	Operational rating
PIER	California Energy Commission Public Interest Energy Research Program
PM	Energy Star Portfolio Manager
PTHP	Packaged terminal heat pump
RD&D	Research, development, and demonstration

ROI	Return on Investment
SZ	Single-zone system
VAV	Variable air volume
VSD	Variable speed drive
W/cfm	Airflow efficiency, watts per cubic foot per minute
W/sf	Power density, watts per square foot
WLHP	Water loop heat pump

APPENDIX A:

Memo Report on Use Cases Pertaining to the Interoperability of EnergyIQ with Other Benchmarking Tools Used to Meet California Requirements

Working Notes | 6 August 2010

EnergyIQ Interoperability

Paul Mathew, Evan Mills

Lawrence Berkeley National Laboratory

Introduction

These working notes document the interoperability of EnergyIQ with other tools. This is a “living document” that will be periodically updated during the course of the project. For completeness, this document includes selected content from a prior memo report on EnergyIQ interoperability produced as a deliverable for Phase 1.

EnergyIQ interoperates with other tools via its web service capability¹. We describe links with the following tools:

- ENERGY STAR Portfolio Manager
- ARB Cool California
- AB1103 Portal
- EnergyIQ iPhone App

ENERGY STAR Portfolio Manager

The goal of the web service link to Energy Star is to allow two-way data exchange between Energy Star Portfolio Manager (PM) and EnergyIQ, so that users can transfer their data between tools and not have to enter data twice.

During Phase 1, we established EnergyIQ as a qualified “service provider” by PM, and completed a fully functioning data exchange between EnergyIQ and PM. This functionality will be added to the live version of EnergyIQ in Phase 2. The process for a user to set up a link between EnergyIQ and PM is as follows:

- User logs into their existing PM account and requests a link to EnergyIQ from the Automated Benchmarking System (ABS) console (see figure 1).

- PM ABS holds the request for EnergyIQ.

- User logs into their EnergyIQ account and triggers the approval of the request for access to their PM account. EnergyIQ is actually utilizing a web service method here on behalf

¹ See <http://energyiq.lbl.gov/SupportPages/EIQ-developers.html> for a description of EnergyIQ’s webservice.

of the user. Once this approval is received by PM, the connection is 'active' and data can now be exchanged.

Figure A1: Portfolio Manager Automated benchmarking Service Console

Option 1: Select Your Current Provider *

Select an Energy Service Provider

ADD >>

Option 2: Inquire About New Services

[Contact an automated benchmarking provider](#)

Learn More About Automated Benchmarking

[About Automated Benchmarking](#)

[Service Providers that Offer Automated Benchmarking](#)

Existing Providers

[Show Activity Log](#)

Provider	Energy Service Provider Status	Buildings Authorized for Automated Benchmarking
EnergyIQ EnergyIQ Customer Support 510-486-5306 Ts & Cs Email Web Site	Connected to ESP View Pending Authorizations Disconnect from ESP	2 Buildings Change Authorization

This example shows EnergyIQ selected as a service provider.

There are two uses cases supported by this linkage:

Use case 1: Data transfer from PM to EnergyIQ, i.e., user has a PM account with one or more buildings, and wants to transfer these data to their EnergyIQ user account. The process will be as follows:

1. User logs into their EnergyIQ account and requests to download their PM data.
2. EnergyIQ sends a request to PM to send data and obtains a receipt verifying the request.
3. EnergyIQ will automatically attempt to receive data from PM within 24 hours. (This maximum response time is guaranteed by EPA. Actual retrieval times are much shorter and are determined by PM ABS load and volume of requests.)
4. EnergyIQ indicates that the data download has been completed or will display an appropriate message on why it wasn't.

Use case 2: Data transfer from EnergyIQ to PM, i.e., user wants to transfer data from their EnergyIQ user account to their PM account. The process will be as follows:

1. User logs into PM and creates the corresponding buildings (if not already done).
2. User logs into their EnergyIQ account and requests to upload data to PM and obtains a receipt verifying request to upload data.
3. PM accepts data from EnergyIQ within 24 hours. (This maximum response time is guaranteed by EPA. Actual response times are much shorter and are determined by PM ABS load and volume of requests.).

EnergyIQ will automatically check to see if the data was stored and indicate to the user that data upload has been completed.

The pilot implementation includes upload/download of building data (type, area, etc.) as well as energy use data. It should be noted that EnergyIQ is not able to create new PM entities or delete existing ones. Therefore, a user will need to create building entities in PM before data is transferred from EnergyIQ to PM.

Pilot testers of EnergyIQ have indicated that this pending data exchange will be highly valuable and significantly increase the likelihood that they will use EnergyIQ.

Under Phase 2, the web-service link to PM, will be fully implemented to allow two-way exchange of all building characteristics and utility data available in the current ABS version. EnergyIQ users will also be able to download ENERGY STAR ratings from PM. Phase 2 implementation will also include development of user interface elements for the web service and data exchange process.

ARB Cool California

ARB's Cool California website provides a link to EnergyIQ on its website, at <http://www.coolcalifornia.org/business-calculator>. It also promotes EnergyIQ on its website at <http://www.coolcalifornia.org/article/save-energy>.

The Cool California website has a carbon footprint calculator that will incorporate EnergyIQ benchmark data using the webservice. EnergyIQ will be an optional module accessible via a dropdown menu (Figure 2).

Figure A2: Arb's Cool California Website has a Carbon Footprint Calculator that will Incorporate EnergyIQ Benchmark Data Using the Web Service.

CoolCalifornia.org
GOVERNMENT • UNIVERSITY • NGO PARTNERSHIP

Sign In | Sign up

Keyword Search

Advanced Search

HOME | INDIVIDUALS | SMALL BUSINESS | LOCAL GOVERNMENT | YOUTH | COMMUNITY ORGANIZATIONS | SCHOOLS | ABOUT US

Home »

Carbon Footprint Calculator
for California Small Businesses

INTRODUCTION | TRANSPORTATION | FACILITIES | PROCUREMENT | SUMMARY | TAKE ACTION

Energy

Electricity: PG&E 46331 \$5 per yr

Percent of electricity from clean energy program: 0%

Natural gas: \$135

Compare your building's EnergyIQ to similar commercial buildings

View annual site energy use in kWh/yr

Select Style: Summary Only Range Bar Ranked Bar Chart Frequency Distribution

0 17 34 51 68 85 102 119 136 153 170

Very Efficient Moderate Efficiency Average Efficiency Very Inefficient

Your Building: 42.3 kWh/yr 88th Percentile

Other Fuels

Fuel oil (gallons/year): 0

LPG (gallons/year): 0

Kerosene (gallons/year): 0

Waste: 14 cubic yards per week

Recycling:

Water:

To compare your building's energy use to other commercial buildings visit [EnergyIQ](#)

Facilities Footprint: 238 mtCO₂e/yr

Calculate/Reset

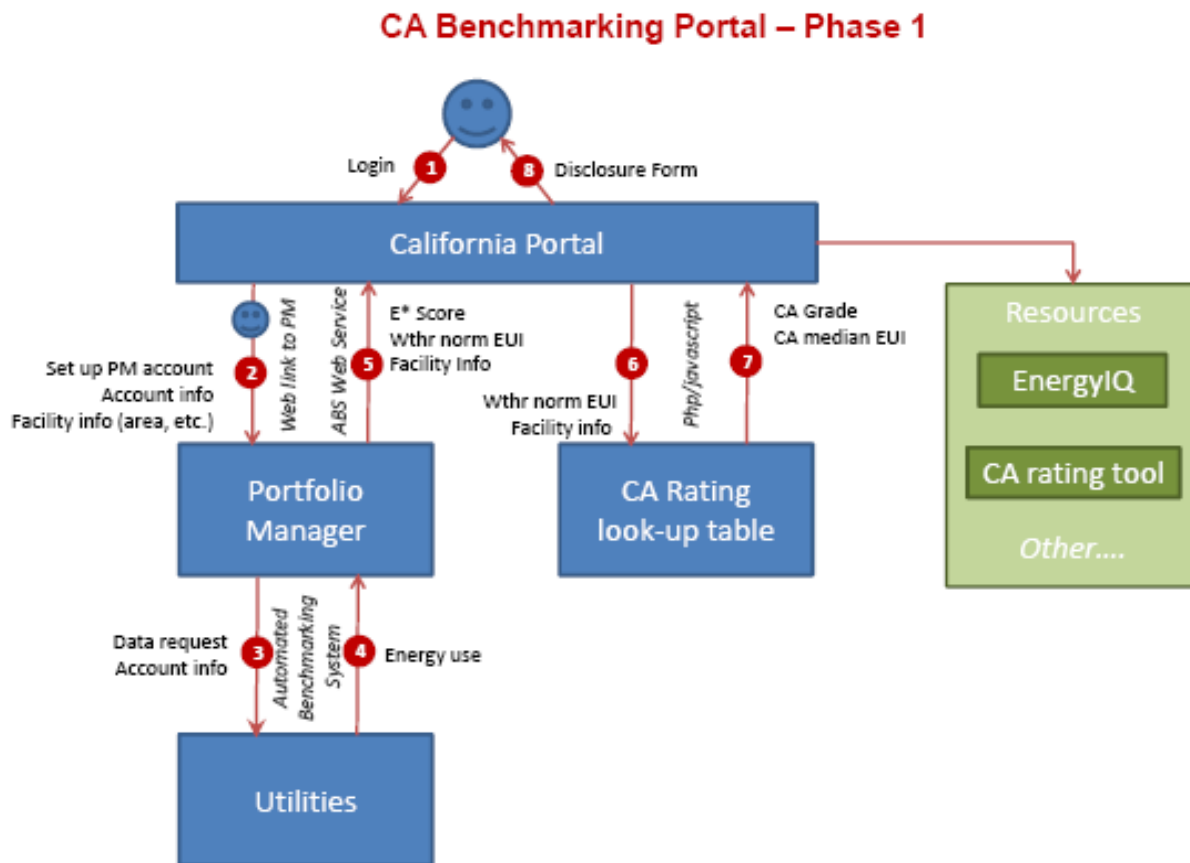
next: Procurement

terms of use | Documentation | FAQ | Tell us what you think

Web Portal for AB1103

The Energy Commission intends to develop a web portal for users to obtain disclosure forms to comply with AB1103. Under Phase 1, LBNL provided technical support to the Energy Commission to develop a scheme for this portal (Figure 3). The purpose of the portal is to provide a single point for users to get the disclosure forms – whether the rating comes from PM or from a California-specific rating table. The portal will also have links to related resources including EnergyIQ. The scheme relies on a web service to exchange data from PM to the California Portal, similar to the way data is exchanged between PM and EnergyIQ.

Figure A3: Conceptual Scheme for California Benchmarking Portal



The schedule for development of the AB1103 portal is uncertain at this time, partially because of uncertainties about the availability of state government IT resources. One option is to allow users to obtain a CA rating from EnergyIQ. The CA rating requires a) data from PM, and b) the CA rating look-up tables developed by Oak Ridge National Laboratory. EnergyIQ has already implemented the data exchange capability with PM. EnergyIQ would also need to incorporate the CA rating look-up tables. This is not currently in the scope of work for Phase 2, but could be part of a future phase of work or could be accomplished in Phase 2 if funding allows.

EnergyIQ iPhone App

The EnergyIQ iPhone app is a native application that leverages an open source project web service (Axis2) to generate plots directly from the EnergyIQ server. Later releases will allow for remote interaction with user's data. This application was sponsored by LBNL's IT division and developed by Martin Stoufer, EnergyIQ's software developer. The application won "First Place" in the application portion of the contest.

Figure 4 shows screen images of data entry and results screens.

Figure A4: EnergyIQ iPhone app



APPENDIX B:

Memo Report on Role of Energyiq in Asset-Based Benchmarking

Memo Report | 7-15-10

EnergyIQ and Asset-based Benchmarking

Paul Mathew & Evan Mills

Lawrence Berkeley National Laboratory

Introduction

The purpose of this memo report is to explore the role and application of EnergyIQ to support asset-based benchmarking that isolates the effects of physical design features from operational practices.

Asset-Based Benchmarking

Several benchmarking schemes are making a distinction between Asset Rating (AR) and an Operational Rating (OR). AR is a measure of the energy efficiency of the physical components of the building, assuming standard occupancy and operational conditions. OR is measure of the energy efficiency of the building as operated, based on actual energy use. AR is especially useful for stakeholders in the sale or lease of buildings, while OR is primarily useful for building operators to track and reduce the energy use of their buildings.

- The U.S. EPA's ENERGY STAR rating is an OR. It is based on one year of actual utility bill data.
- ASHRAE's BuildingEQ label includes both an AR and an OR. The OR is based on ENERGY STAR. The AR is calculated using a simulation model and compared to the Standard 90.1 baseline.
- The European Performance of Buildings Directive uses both AR and OR. In the UK, for example, the Energy Performance Certificate (EPC) has an AR accompanied by a recommendations report. The Display Energy Certificate (DEC) has an OR based on metered data.
- California's AB1103 uses an OR even though an AR is more appropriate because it is a disclosure at the time of sale or lease. This may be in part because at the time AB1103 was conceived there were no AR programs that were readily usable.

The definition and implementation of AR and OR vary across these programs and there are no standard definitions for AR and OR. While a more comprehensive discussion of the AR methodology is beyond the scope of this memo report, we would like to highlight a few key methodological considerations:

- AR invariably requires a model-based approach, typically involving whole-building simulation. A model of the building is generated based on as-designed or as-built conditions and run under standard operating conditions and compared to baseline – which could either be a building code baseline (e.g. ASHRAE standard 90.1 for BuildingEQ) or an empirically derived benchmark such as median energy use intensity for peer buildings.
- A clear and detailed set of rules are required for ensures that the AR is generated in a consistent manner, especially because simulation models require a large number of input assumptions. The COMNET program has developed such a set of rules, which includes modeling guidelines for building characteristics not covered by Standard 90.1 [COMNET 2009]. ASHRAE is considering use of COMNET in the BuildingEQ program.
- The AR and OR methodology needs to distinguish between operations and occupancy characteristics. An OR may normalize for several occupancy parameters (e.g. number of occupants, occupancy schedule, number of computers), while an AR will also normalize for operations (e.g. it will assume standard operating schedules of HVAC, lights, etc.). Differences between AR and OR typically indicate poor controls (e.g. stuck economizers, lights left on, etc.). Some items fall in gray areas, e.g. control system capabilities that may not have been activated. The methodology needs to distinguish operations and occupancy characteristics and whether they have been normalized. Depending on the application of benchmarking, a user may want to include or exclude different characteristics from the normalization for an AR. For example, a portfolio owner who has in-house controls expertise may prefer to exclude control limitations from AR because they believe they can adequately address controls limitations through proper operations.
- The AR methodology needs to distinguish between as designed and as built. As designed, may not include effects of poor construction quality, for example.²

In addition to these technical considerations, a major practical consideration is the time and resources required to collect the data and generate a simulation model. ASHRAE's BuildingEQ label will require an on-site survey by an energy professional. Many existing buildings may not even have current as-built drawings, let alone system and component specifications. More research is needed on resource efficient means to generate an AR. In particular, empirically based approaches have the potential to offer cruder but resource efficient means to generate an AR that may be appropriate for non-statutory uses. This is discussed further in section 3.2.

² It is not clear, based on the documentation reviewed for this report, whether BuildingEQ requires as designed or as built asset characteristics.

Role of EnergyIQ

Explain the Reason for the Rating

Building-level AR and OR indicate relative scale of the opportunities to improve assets or operations. For example, a building whose operational rating is much lower than its asset rating should probably focus on retro-commissioning before considering asset retrofits. However, the building-level AR and OR are limited in their ability to provide more specific information on efficiency opportunities – they tell you where you are, but not why. This is where EnergyIQ can add value.

Benchmark a suite of asset and operational metrics at the system and component level.

System and component level metrics improve understanding by creating closer connections between performance ratings and the underlying causes [Bordass 2008a]. Both the European EPC and BuildingEQ aim to provide system level information and recommendations to improve performance. EnergyIQ supports this objective through its suite of system level metrics. Table 1 shows selected asset and operational metrics that are currently (or in future releases could be) available from the CEUS dataset in EnergyIQ.

Table B1: Selected Asset and Operational Metrics in EnergyIQ (* indicates future version of tool)

System	Asset metrics	Operational Metrics
Lighting	Power density (W/sf) *	Lighting hours
Ventilation	Airflow efficiency (W/cfm)	Fan hours*
Cooling	Chiller kW/ton RTU EER/SEER	Chiller system hours*
Heating	Boiler efficiency (%)	Boiler system hours*
Service Hot Water	Heating efficiency (%)	Pump hours

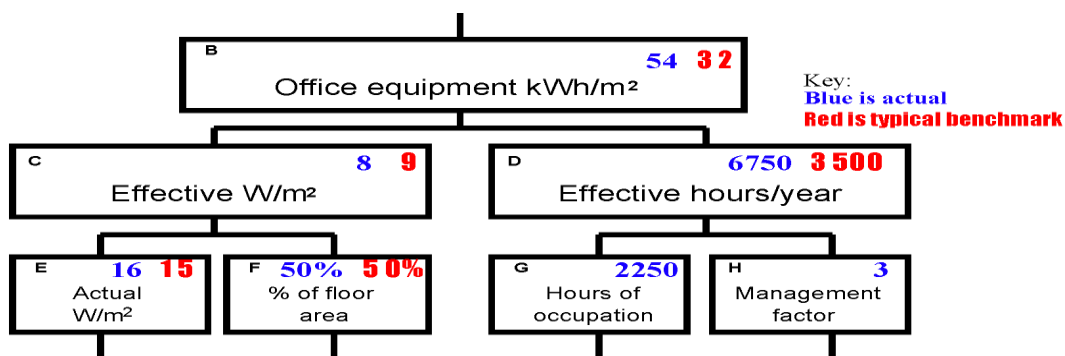
Future versions of EnergyIQ could further support AR objectives by:

- Labeling the metrics as asset vs. operational metrics.

- Generating a dashboard of asset metrics

- Presenting a hierarchical tree of metrics (Figure 1) that allows a user to quickly grasp the key opportunities in assets vs. operations [Bordass 2008b].

Figure B1. The Tree Diagram Approach (Based On Cibse Tm 22) Can Summarize the Breakdown of Annual Electricity Use and Compare It with Benchmarks at both the System and Component Levels



In this example the main cause of high annual energy use is the excessively long annual equivalent operating hours (Box D), owing to much of the equipment being left running at nights and weekends, often unnecessarily [Bordass 2008b].

Provide a list of actions to improve asset ratings.

EnergyIQ's actions report will provide a list of actions that include both asset and operational measures. Future versions of EnergyIQ could further support AR objectives by:

Allowing the user to filter the list of actions as asset-related vs. operations-related.

Providing a summary of savings potential from asset-related actions vs. operations-related actions.

Provide information on the preponderance of asset types within a benchmark peer group.

EnergyIQ's "features-based" benchmarking allows users to assess the extent to which various types of assets have penetrated their peer group. This is important because it may help overcome the perceived risk of under-deployed technologies. Most of the features currently available in EnergyIQ are in fact asset characteristics, and therefore EnergyIQ already supports this objective fairly well.

Provide an AR that is coarser but less data intensive?

As we explained in section 2, an AR is a calculated rating that invariably requires a model-based calculation approach involving considerable data collection. For instance, one of the building assessors in the ASHRAE pilot program described the process as: "The engineer not only examines building energy use and carbon footprint, but tests and measures the building environment and meets with building engineers on site. After spending time onsite, we then work with the building owner to understand the building systems and provide goals and suggestions on future improvements. The intent is to create a path so that more and more buildings can move from a low grade to a top grade."

This level of rigor in data collection may be necessary and appropriate for BuildingEQ and the European EPC because they are intended for labeling or statutory use. However, the level of

effort may be beyond an acceptable threshold for many building owners who are not necessarily looking to be labeled but would like to get a rough assessment of their asset efficiency.

We are exploring whether EnergyIQ can provide a coarser but less data intensive means to generate an AR. Specifically, we are considering an approach that leverages the CEUS database simulation models as follows:

- Collect selected occupancy and operational characteristics for the subject building (i.e. the building to be assessed).
- Select a peer group for comparison from the CEUS dataset. The peer group would be selected based on currently available filters (building type, size, vintage, climate zone).
- Change the occupancy and operations characteristics in all the peer building simulation models to reflect the subject building's occupancy and operations characteristics. This is the adjusted peer group.
- Run the adjusted peer group simulation models using the weather file for the location of the subject building.
- Compare the subject building's EUI to the EUI distribution of the adjusted peer group. The subject building's percentile score effectively serves as an AR because the peer group buildings have the same occupancy and operational characteristics as the subject building.

In order for these updates to be implemented within EnergyIQ, a number of issues will need to be resolved:

- We will need to confirm the extent to which the occupancy and operational characteristics can be parameterized in the simulation models. (This will be done as part of the current Phase 2 scope of work.)
- It would be desirable to develop a set of criteria for selecting a peer group. Currently, EnergyIQ allows the user to select a peer group based on their judgment. For instance it could be argued that the climate zone filter could be ignored because the models will be run with the subject building's weather file. On the other hand, buildings in different climate zones may be expected to have different assets and therefore it may not be reasonable to compare them.
- Ideally, the weather file would be for the year of the subject building's data. If the weather data is difficult to obtain a typical weather year could be used - but that would reduce accuracy, especially if the subject building's data is from an extreme weather year.

A related issue is the accuracy of the asset characteristics in the CEUS models. The CEUS survey included a large number of asset characteristics, driven by the need to develop calibrated simulation models for each of the buildings. However, the extent to which these data were actually collected for each asset characteristic, varied significantly. In many cases, defaults were used based on proxy variables such as age, and it may be difficult to determine the inaccuracies

from such assumptions. Nevertheless, we believe that this AR approach may strike a good balance between rigor and ease of data collection for selected applications.

Conclusion

Several benchmarking schemes are making a distinction between Asset Rating (AR) and an Operational Rating (OR). EnergyIQ can support the AR schemes in the following ways:

- It can provide a rich set of system and component level metrics that can help users identify the underlying causes for the rating.

- It can provide a list of recommended actions to improve asset ratings

- It can provide the user information on the preponderance of different asset types in a peer group of buildings.

EnergyIQ also has the potential to provide a building level AR that is coarser, but not as data intensive as BuildingEQ, using the CEUS simulation models. Most of the technical capability to generate such an AR will be implemented in Phase 2. Therefore, an AR feature could be built in relatively easily in a future version of EnergyIQ.

REFERENCES FOR APPENDIX B

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APPENDIX C: Engineering Methodology

Note that the latest description of our engineering methodology can be found at the following public website: <https://sites.google.com/a/lbl.gov/energyiq/methodology/datasets>

Benchmarking Datasets

The [CEUS](#) provided the initial peer-group data that underlay the benchmarking process for EnergyIQ. CEUS is a highly detailed survey of approximately 2800 non-residential premises across California, based on a stratified random sampling across utility regions, climate zones, building types, and building size. In contrast to surveys relying on self-reporting, CEUS employed on-site surveys of building characteristics and monthly utility billing data. Short-term data logging and/or interval metering was performed at some sites. Energy intensities were derived from calibrated simulations, based on characteristics collected at the sites. The CEUS data are of unprecedented quality and detail. This enables a higher level of granularity in the benchmarking, ranging from campuses, to buildings, to systems, and to components.

A national dataset, based on the [CBECS](#) provides an alternative reference point for benchmarking outside of California. The CBECS is a national sample survey that collects information on the stock of U.S. commercial buildings, their energy-related building characteristics, and their energy consumption and expenditures. A total of 5,215 buildings across the country were statistically sampled. Commercial buildings include all buildings in which at least half of the floorspace is used for a purpose that is not residential, industrial, or agricultural, so they include building types that might not traditionally be considered "commercial," such as schools, correctional institutions, and buildings used for religious worship.

The CBECS was first conducted in 1979 and is currently conducted on a quadrennial basis by the Energy Information Administration (EIA). The CBECS is conducted in two data-collection stages: a Building Characteristics Survey and an Energy Suppliers Survey. The Energy Suppliers Survey is initiated only if the respondents to the Building Characteristics Survey cannot provide the energy consumption and expenditures information, or the information provided fails edits within the survey instrument. The Building Characteristics Survey collects information through voluntary interviews with the buildings' owners, managers, or tenants. Respondents are asked questions about the building size, how the building is used, types of energy-using equipment and conservation measures that are present in the building, the types of energy sources used, and the amount and cost of energy used in the building.

Data Import from the ENERGY STAR Portfolio Manager

EnergyIQ users can import building data directly from ENERGY STAR Portfolio Manager to EnergyIQ. But there are some things you need to know before you start:

- **Importing your data is not instantaneous.** It may take up to 48 hours for your building data to appear in EnergyIQ.
- **Importing your data is all or nothing.** When you import, all of your energy data for all of your buildings will be imported.
- **Portfolio Manager data overwrites other data.** Building data is organized by building name. Portfolio Manager Data with the same building name as EnergyIQ buildings will overwrite existing EnergyIQ data. The data from buildings with unique EnergyIQ names will not change.
- **New/Updated data overwrites old data.** Updating your building data works the same way. All of the new data replaces all of the old data.

Procedure (What You Do):

1. Select the "Get Started Now" link under the Automated Benchmarking section of the Portfolio Manager homepage.
2. Select **EnergyIQ** from the *Option 1: Current Provider* drop down list; Add.
3. Accept the Terms of Use.
4. Set the access level to **Release new buildings and update existing buildings**.
5. Select both buildings; Update List; Continue.
6. *Select All* for Meters. Select *Read Only* for each Meter; Continue.
7. Login to EnergyIQ and navigate to the My Buildings section of the site. Click on "Connect to Portfolio Manager." This will make the initial request to connect to PM.
8. Provide the Portfolio Manager User ID.
9. When the request has been acknowledged in EnergyIQ, The button changes to "Import from Portfolio Manager." The request will be submitted and you will be immediately notified if submission was successful or not.
10. When the import has been completed, you will receive an email notification from the system that the import is complete.
11. Next time you visit or refresh the My Buildings section of EnergyIQ, you should see your imported buildings and energy data.
12. If you add new buildings in Portfolio Manager after you already have a set imported into EnergyIQ, They may not show up when you try to import them.
 - a) You have to authorize all new Buildings, Meters, and Monthly readings in Portfolio Manager so they can be read by EnergyIQ.
 - b) You will have to remove the entry for your "Portfolio Manager User ID" from the My Info page and then re-connect and re-import each time new of buildings, et. al., are ready to be exported from Portfolio Manager.

Import Strategy (What We Do):

Goal: To maximize the amount of a User's data in Portfolio Manager into annual use aggregations in EnergyIQ.

Invariants: Portfolio Manager provides period data in a descending order--latest period first, earliest period last. A given period meter data may not fall on a calendar month boundary. In fact, a period may be 1 month, 2 months, 1.5 months, etc.

Strategy:

1. For each building:
 - a. For each meter:
 - b. Extract and store each consecutive monthly period measurement into a Series
 - i. Drop Series that do not have at least 12 months of measurements. Those which do become Annual Series and are added to the User's Annual Series Collection.
 - ii. Monthly periods not separated by a month period between them whose end and begin dates are 4 or more days apart are not considered consecutive and constitute the beginning and end of different (Annual)Series.
 - iii. Monthly periods not separated by a month period between them whose end and begin dates that are 3 or less days will have the missing days' values imputed and added to the prior month [*See Equation A*]
 1. If an Annual Series has more than 1 gap of three days or less in a 30 day period, that series is invalid and is dropped from further calculations.
 - iv. If a meter has less than 1 year of data, then message the user that EnergyIQ did not import data from that meter.

Equation A:

Value imputation between two consecutive months that have a gap of missing data between them not to exceed 3 days.

$$V_{pm} = V_{pm} + (((V_{pm}/days_{pm}) + (V_{em}/days_{em}))/2) * days_g$$

Where V_{pm} is the value of the previous month,

$days_{pm}$ is the days of the previous month,

V_{em} is the value of the ending month,

$days_{em}$ is the days of the ending month, and

$days_g$ is the number of days in the gap to interpolate values for.

Features Benchmarking

Most benchmarking methods focus strictly on using whole-building energy use to develop figures of merit. EnergyIQ accepts end-use energy data and also employs what we refer to as “features benchmarking.” The premise is that there is value in benchmarking the presence or absence of certain features in a binary or qualitative fashion. Features benchmarking can also be based on equipment efficiencies (e.g. kW/ton) or product categories (e.g. types of lighting control), where data are available. With this information, correlations between features and energy intensities are used to help identify promising actions.

The CEUS was remarkably detailed in documenting building features and operational characteristics, with 92 features available for ranking. CBECS has a smaller range, with only 14 features available. EnergyIQ allows for the user to aggregate results by count or by weight. User buildings may not be directly entered for comparison in the feature graphics, but allows the user to identify the efficiency characteristics of specific systems, components, and operational characteristics.

Filtering to Define Peer Groups

The user can filter the data at any point by building type (62 options), location, vintage, floor area, and/or size.³ The user can describe portfolios of buildings and evaluate them individually or in aggregate. EnergyIQ speeds the user’s path to useful results by allowing the user to visually browse a wide variety of metrics and visualizations generated dynamically based on the peer-group data via the web interface.

By filtering the datasets to filters that most fit the user’s building, users can obtain a benchmark that realistically fits their building. Some users may find that there are only a few buildings in their peer group if filtering is too narrow. Attached is a matrix of available buildings based on filters.

Upgrade Analysis

For California buildings, EnergyIQ offers the capability to do an “upgrade analysis” to examine the impact of implementing a select group of 50 distinct energy efficiency measures, with several possible efficiency levels per measure.⁴ The methodology uses the same subset of CEUS buildings that match the user’s peer group, and then present the range of savings for those peer buildings based on the implementation of those measures on the eQUEST models for the underlying peer group. Itron’s DrCEUS Energy Efficiency Measure Analysis (EEMA) module

³ Details here:

<https://docs.google.com/a/lbl.gov/viewer?a=v&pid=sites&srcid=bGJsLmdvdnxiLbmVyZ3lpcXxneDozN2I5NmE5OGFmYWZmNDU2>

⁴ Details:

<https://docs.google.com/a/lbl.gov/viewer?a=v&pid=sites&srcid=bGJsLmdvdnxiLbmVyZ3lpcXxneDo2NzQ4NzFkNDBkNTYyZGU2>

was used to perform the measure runs -- the result is over 65,000 measure-building combinations.

Savings ranges include three values: lower 25 percentile, median, and upper 75 percentile. Savings are expressed as a percentage of whole-building energy use for the metrics site energy, source energy, cost, and carbon emissions. Thus, the percentages are typically in the low single-digits for each highly-specific measure. Users can choose to view savings for total energy or for gas and electricity individually.

A qualitative indicator of Return On Investment (ROI) is also provided. These are based strictly on likely cost-effectiveness, without reference for the level of savings.

The measures are, by definition, only applied to those buildings for which they are applicable (e.g., CFL lighting only to those buildings). Note that when looking at whole-building metrics, HVAC interactions are included. In heating climates, this will dilute savings from lighting and plug loads. A detailed description of each measure is provided via tooltips in the online GUI.

Analysis Method and Overview

The measures incorporated into the Upgrade Analysis were limited to those that were already available from the DrCEUS EEMA module.

Basic Measure Organization

The first tab of this file (EIQ_MeasNames.xlsx) presents a summary of the measures and the parameters used for each measure run. These are the descriptions that would likely be used in the EnergyIQ interface. The fields in this table are:

End Use Measure Group

A high-level grouping of the measures. Examples are (building) Envelope, Outdoor Lighting, and Packaged HVAC.

Measure Category

A secondary, lower-level grouping of the measures corresponding to a specific technology (CFLs, linear fluorescents, etc.) or configuration (package, split-system, etc.)

Measure Name

A description of the actual measure as implemented. Each of these measures will have a high-efficiency value (*EE-Value* field) or configuration, and some also have a baseline efficiency value (*Base-Value* field) and a corresponding description of the basis for these efficiencies (*ValueBasis* field).

Measure Groupings

There are 10 End Use Measure Groups, each encompassing a different number of detailed measures. The EU measure groups are:

Envelope - includes several roof measures, wall insulation, and window measures.

Outdoor Lighting - includes photocell control, CFLs, and T12-to-T8 linear fluorescent conversion measures.

Indoor Lighting - includes CFLs, and T12-to-T8 linear fluorescent conversion measures, as well as a high-level, overall reduction in the total lighting power density (LPD).

Service Hot Water - includes high-efficiency storage water heater and boiler options, storage tank insulation, and pipe insulation.

Refrigeration - measures are primarily those applicable to remote/rack types systems. As such, these measures all apply to the rack system (i.e. compressor, condenser, sub cooling, controls), and it does not include and display case measures.

Packaged Heating, Ventilating, Air Conditioning (HVAC) - contains by far the most individual measures and covers most unitary HVAC systems, as well as economizers for those systems. For the measure analysis, cooling and heating efficiencies are actually separate measures [these might be post-processed and combined though]. The packaged HVAC systems represented are packaged and split-system single-zone systems (SZ) cooling, air source heat pumps (ASHP), water loop heat pumps (WLHP) packaged terminal heat pumps (PTHP), and gas furnaces (GF). For the units with cooling and electric/HP heating, three levels of cooling efficiency were analyzed: Above Standard (AboveStd), Better Efficiency (BetterEff), and Best Efficiency (BestEff). These names are encoded into the measure names rather than the actual efficiency values, but the efficiency values are available. For gas heating, three levels of efficiency were also simulated, but the actual percentage value is used in the measure name. Other notes about these measures are listed below:

For the SZ & ASHP cooling units, two size categories were used for consistency with codes & standards minimum efficiencies: <5.42 tons (SEER rated equipment) and ≥5.42 tons (EER rated equipment).

For the WLHP and PTHP units, only the efficiency was varied, though technically PTHP minimum efficiencies vary by unit capacity.

The data used to set the three efficiency levels for all HVAC equipment including chillers.⁵

Built-up HVAC - does not include high-efficiency systems, but rather conversion to or modifications of these systems. The measures include converting a constant-volume systems to a Variable Air Volume (VAV) system, reducing VAV system minimum airflow percentage, changing electric to gas reheat, and adding an enthalpy economizer.

⁵ Details:

<https://docs.google.com/a/lbl.gov/viewer?a=v&pid=sites&srcid=bGJsLmdvdnxbmVyZ3lpcXxneDo1YWUwZjZlZjU5ZjBjZjMx>

HVAC Chillers - has the second most numerous measures, due to the large number of chiller type/condenser type combinations. The primary measures are high-efficiency chillers, but chilled water reset is also included. Centrifugal, reciprocating, screw, and scroll chillers in water-cooled or air-cooled options are all available. As for the packaged HVAC systems, three levels of efficiency were modeled for each chiller/condenser configuration. Note that size (ton) categories were not used for these measures for simplicity (though these are used for efficiency standards), and because in practice, each chiller/condenser configuration is usually applied for a specific cooling load size range. For example, reciprocating air-cooled chillers might typically be used for smaller applications, while centrifugal water-cooled chillers would be used for larger applications.

HVAC Boilers - includes high-efficiency hot water and steam boilers. Three levels of efficiency were also modeled for these measures.

HVAC Motors - include premium efficiency motors for HVAC hot/cold water circulation pumps and ventilation fans, as well as (Variable Speed Drive) VSD or two-speed control for pumps.